3-D Digitizing and Representation of Historical bound Atlases and Maps using low cost solutions

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Old bound atlases and maps constitute a particular case of cartographic documents, with respect to their digitizing. This is mainly because of the curved, undulated and in general irregular surface of their pages, which creates specific demands and difficulties when converting them to digital form. In order to properly digitize bound atlases and maps their metric quality has to be preserved after digital conversion: this means that after converting them to digital form, they can be used for conducting accurate measurements on their surface, such as e.g. obtaining (originally) curved distances by measuring on the digital copy of an atlas page.

In order to achieve this, a two-step procedure is followed, involving:

- The creation of a 3D digital surface model (DSM) of the irregular surface of an atlas page and the creation of the respective orthoimage.
- The possibility to measure 3D distances on the DSM, as if using the original analog copy -in other words to fully retain the metric quality of the map on the digitized document. This is performed by the use of the special procedure that calculates the slope distances between points on the maps' surface hence the creation of an unwrapped version of the map.

In our work we attempt to accomplish this task by means of low cost solutions such as free and home-made software tools. For the purpose of the research an historical 18th century bound atlas by J. B. Homann is used; pages are scanned in different parts of the book, in order to accommodate for various curvatures and irregularities in page shape.

The first step i.e. the creation of pages' DSMs is accomplished by means of a two-fold procedure, namely: a low cost 3D technique to extract the geometry of the object's relief and consequently the scanning of the atlas

map and registration of the map image on the DSM using automated procedures.

To visualize better the example we have deformed and placed a printed page of a regular grid (in a distance of 2.5cm) of dot targets in the centerfold of a book that follows the shape of the typical atlas book. Additionally the pages were captured photographically in order to be recorded using a multi photo phototogrammetric approach. Three images of the central, left and right location above the page were captured using a 10MPixel calibrated FujiFilm FinePix Real 3D W1 (*Figure 1a,1b,1c*).

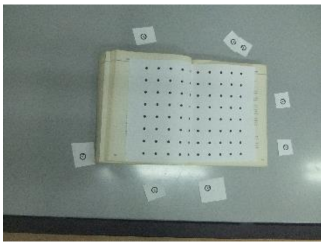

Figure 1a. Left Image

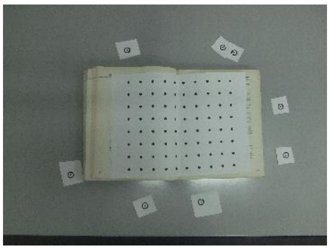

Figure 1b. Center Image

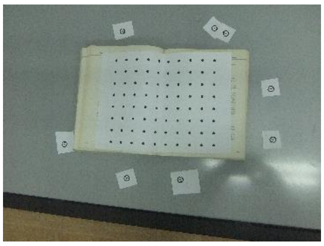

Figure 1c. Right Image

The software that was used is Photomodeler Scanner 2012 which has the ability to provide in an easy and rapid way the 3D model of any textured object or of a grid covered surface that lacks texture, in a fully automated procedure. Therefore the DSM and the respective orthoimage of the grid page were created (*Figure 2a & 2b*).

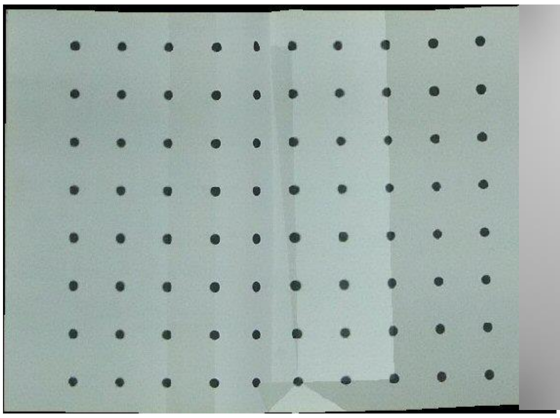

Figure 2a. Orthoimage generated by Photomodeler Scanner 2012.

Figure 2b. Depth map of the DSM. Each gray tone (0-255) represents an elevation of 0.1mm

The second problem to be solved was the creation of a deformation of the orthoimage provided from the photogrammetric process, in a way to obtain the unwrapped version of the map. For this purpose a special algorithm was developed that aims to unwrap in the first stage of the procedure, for every row in the ortho image a respective unwrapped image row, so that the distance between every pair of points is the actual slope distance and not the x-planimetry distance. For this reason the DSM was used to calculate for every point in an image row its slope distance from the first pixel of the row. Since the actual location of every pixel in a row is calculated and since it is also possible to calculate the distance between the first and last pixel in each row, a similar to a stretching procedure is applied in every line of the ortho image (image 3a and 3b). In the next stage, the similar deformation is applied so that every column of the previous stretched image is unwrapped using the slope distances between the points in the same column (using again the DSM information). In this way we can assume that the pixels of every image row and column are transposed to their originally created flat paper location.

Image 3a. Sample of a single line of the grid targets. The distance between the 5th and 6th grid points is smaller (30 pixels) in the center of the image were the page is folding.

Image 3b. The same line of grid targets is unwrapped using sloped distances and the stretching procedure. The distance between the 5th and 6th point has changed to 39pixels which is close to their correct value (40 pixels).

The results of the algorithm are tested by measuring curved distances on the original analogue atlas and using them as the ground truth for the comparisons.

In our sample of the folded page of grid targets, the unfolding procedure gave the correct distance between the points (2.5cm) with accuracy better than 1mm, while the error of the dislocation of the grid points on the orthoimage was more than 2mm especially in the center of the folded page.

The quality of the produced unwrapped version of the map depends on the quality and density of the DSM. Even if the quality of the produced DSM is perfect (better than 0.1mm) when the density of the DSM is not high the resulting unwrapped

version of the map will be erroneous. Additionally the application of conventional photogrammetric techniques is appropriate to all kinds of maps on Atlases since they can be of low texture. Therefore another approach must be found to extract the DSM of the maps and provide the respective orthoimage using a scanning or photogrammetric technique. The DSM can be provided only by the use of photogrammetric software but also from 3D structure light scanning devices. Our next aim is to use such a device to provide in a better density and quality the DSM and create a respective orthoimage using high resolution scanning of photographic sensor and apply the unwrapping algorithm to provide a more accurate result.